SCADA SYSTEMS AND LESSONS LEARNED

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INTRODUCTION

This paper presents information on Supervisory control and data acquisition (SCADA) systems and lessons learned from several SCADA projects. In addition general information is presented on a Lock and Dam SCADA project designed by the Little Rock District.

SCADA DEFINITION

SCADA systems are mainframe, workstation, or PC computers interfacing with field devices accessed through remote terminal units (RTU's) or programmable logic controllers (PLC's). These systems collect data and/or perform control actions on field devices. Operators and programmers interface with the computer system via a man machine interface (MMI). SCADA systems minimize the responsibilities of the operator and in many cases eliminate the need for a full time operator.

SCADA STANDARDS

The American National Standards Institute (ANSI) developed ANSI C37.1 (also known as IEEE C37.1), "IEEE Standard Definition, Specification, and Analysis of Systems Used for Supervisory Control, Data Acquisition, and Automatic Control." ANSI C37.1 applies to systems used for monitoring and controlling substations and powerplants. This standard contains useful definitions and features for SCADA systems.

In 1992 a standard was published, which established recommended practices for master station equipment communications protocols to remote equipment. This standard is IEEE 999, "IEEE Recommended Practice for Master/Remote Supervisory Control and Data Acquisition (SCADA) Communications."

The Corps of Engineers is developing military standards for electrical distribution type SCADA systems. No standard civil works specifications are distributed by HQUSACE. The Little Rock District has developed SCADA specifications for tainter gate control on Lock and Dam SCADA systems and specifications for Military Water Distribution SCADA systems. These specifications are available on request.

Even though the Federal Information Resources Management Regulations (FIRMIR) standards are not in effect at this time, I would be remised if I did not mention this outdated standard. FIRMIR requirements define hardware and software standards. These do not typically apply to most SCADA software systems because of the specialized nature of the SCADA software, however some hardware may fall under the requirements of FIRMIR regulations. The FIRMIR standards are in transition and may not be in effect at the time of a new design. The designer should check with his District's Information Management Office for the status of FIRMIR requirements.

JUSTIFYING SCADA SYSTEMS

SCADA systems are increasing in use in many Government facilities. Many systems are justified due to loss of personnel or due to safety considerations. The Little Rock District has justified SCADA systems for the following reasons:

- The existing controls are obsolete and spare parts are not available. Use a SCADA system with PLC modules to interface with the existing essential relay controls. Non critical relay-based controls can be replaced with the PLC.

- Personnel are required to operate the equipment during adverse weather conditions such as ice and lightning which may cause the operator to compromise his safety. A SCADA system can provide economical remote control which allows the operator to control the system from a safe environment.

- At unmanned dams on the Arkansas river where new hydropower plants are built the possibility of a unit load rejection would require immediate control of the gates to maintain pool operation limits and to prevent possible severe river surges. A SCADA system can be located in a remote location and provide timely control actions at the unmanned dam during a load rejection.

- Loss of personnel due to cutbacks has reduced the number of operators to minimal levels. We have operators required to control more than one facility as well as to perform maintenance on the facilities. Remote control SCADA systems allow the operator to better utilize his time and eliminate the need to move between facilities several times a day.

MAINTENANCE OF SCADA SYSTEMS

SCADA systems are complex and require trained personnel to maintain and operate them. Many existing maintenance personnel are antiquated when it comes to current electronic technologies. Our SCADA systems are usually supported by specialized engineers or technicians. In some cases SCADA systems are supported by maintenance contracts. If a SCADA system is to be specified then it is important to consider how it will be maintained. Economic analysis used to justify SCADA systems should include the cost for future maintenance. We recommend that government maintenance personnel be selected prior to contract award and that person participate in the review of SCADA system.

SCADA SYSTEMS IN TODAY'S MARKET

Where Large systems used to be based on custom developed hardware and software manufacturers, smaller systems are being developed from generic software packages and off the shelf RTU hardware components. There are more than 130 software packages available in the market [1]. There are approximately 120 data acquisition hardware manufacturers [2]. The diversity of the software and hardware systems allows many options in the development of SCADA systems. The demand for large SCADA systems has decreased [3]. This will improve the competition in SCADA systems since the large SCADA contractors will be providing competition for the smaller SCADA contractors.

Information gathered by Pennwell Research shows that 59 percent of planned utility-based SCADA systems will use PC-based operating platforms, 27 percent will use workstation platforms, 13 percent will use minicomputer platforms, and 1 percent will use mainframes.

COMMUNICATION SYSTEMS

Communication systems for utility systems utilize radio systems approximately 42 percent of the time, fiber optics systems are being used approximately 30 percent, leased line systems and microwave systems are being used approximately 14 percent each[3]. The most dependable communications means is a fiber optic transmission system, but the installation costs of radio systems makes it more used. Telephone lines are the least desirable means of communications based on reliability, but in many cases are the only means based on project budget or radio interference problems. Microwave systems are being phased out in the Little Rock District due to maintenance costs and the Governments desire to free up these frequencies for use by others.

CHANGES IN MASTER STATIONS ARCHITECTURES

Early SCADA systems relied on mainframe computers operating with proprietary software for master stations. These mainframes interfaced with dumb RTU's and contained predominantly all logic in the master station. Workstations operating in a UNIX type environment gradually started replacing the bulk of mainframes computers. RTU's started sharing part of the processing load and distributed architecture became the going trend. Now we have personnel computers that are replacing the early mainframes and doing it faster. RTU's are continuing to take more of the processing load with master stations being managers and database keepers.

SCADA PLC EQUIPMENT VERSUS HARDWIRED RELAY LOGIC

From our experience, PLC equipment is not as reliable as relay logic systems and should not be the only source for control of essential control systems. It is recommended to provide relay-based controls as a backup to SCADA systems for essential control systems. We always maintain the hardwired relay controls at the local motor control centers for our equipment. The SCADA system parallels these hardwired controls. In case of SCADA problems, the equipment can be operated locally.

Transient Surges

Due to the high probability of lightning strikes and poor electrical distributions lines in Arkansas we require extensive TVSS equipment. Our first SCADA system was plagued by interruptions due to surges. We installed additional TVSS equipment and still had failures. Our initial TVSS equipment was of poor quality and was replaced with better quality equipment which helped with equipment outages. However, we still had equipment failures due to surges. We performed in depth studies to determine the cause of the failures and finally concluded we were bypassing our TVSS equipment because of poor installation techniques. The incoming and outgoing wiring to series TVSS devices were coupling during large surges and disrupting our equipment. We separated the incoming from the outgoing wiring and solved most of our surge problems.

We typically install TVSS equipment at all PLC I/O points, PLC power supplies, and electrical distribution panelboards.

Equipment Location

Conditions in Arkansas dictate that PC and PLC/RTU equipment be located in conditioned environments. Even though the most common RTU/PLC industrial equipment is rated at or above 122 degrees Fahrenheit (50 degrees Celsius), our experience is that the equipment will not operate reliably at these temperatures. We recommend that SCADA equipment should not be continuously operated above 100 degrees Fahrenheit (38 degrees Celsius). Provide condition spaces if equipment must be operated in ambient temperature above 100 degrees F.

Sole Source Justification

We have developed a standard specification for the control of tainter gates for the Arkansas river Lock and Dam systems. This specification will be used for all future Lock and Dam projects for the Little Rock District. We desire to obtain sole source justification for all future Lock and Dam SCADA systems. We will sole source the SCADA software portion only and not limit hardware selection. While this may limit software selection, competitive bids should be received because we are not sole sourcing an integrator. By sole sourcing a particular software system we are able to assure compatibility between each Lock and Dam and ease maintenance requirements. We have not overcome this hurdle with our contracting branch, however we endeavor to achieve sole source justification.

DARDANELLE LOCK AND DAM SCADA SYSTEM

Background

One of Little Rock Districts latest Lock and Dam that is being implemented with a SCADA system is Dardanelle Lock and Dam on the Arkansas River. Dardanelle Lock and Dam contains one 600-ft lock chamber and 20 tainter gates. The tainter gates are currently controlled from individual motor control centers located on the dam. Many of the existing remote indicating selsyn receivers and transmitter have failed and replacement parts are not available. Operation of the gates from individual motor control centers works without problems except during adverse weather conditions during which the operator's safety is compromised. There is no need to control the Lock from the SCADA system since the existing upstream and downstream hydraulic controls are still functional and shelters provide adequate protection for the operator. Certainly the operators desire control of the lock yet there is no economic advantage to providing SCADA control for the lock.

SCADA Operational Limits

We do not allow the SCADA system to raise or lower the tainter gates on the sill due to safety considerations. The operator must still go to each gate to perform this operation. The reason for this requirement is to prevent loss of life of fishermen trapped near the gates and to prevent the gates from being lowered onto an obstruction which could cause the cables on the hoist drum to slip out of their grooves. A CCTV system which could allow the operator to view the gate sills would negate this requirement and allow the gates to be raised or lowered onto the sill from the SCADA system. The Dardanelle Lock and Dam CCTV system has not been funded at this time. We are in the process of developing a CCTV system in conjunction with a SCADA system for the remote operation of Wilbur D. Mills Lock and Dam.

System Configuration

The Dardanelle SCADA system consists of a single master station one report printer, one alarm printer, two PLC's, I/O modules, UPS, PLC monitors, pressure transducers for level indication, potentiometers for gate position indication, rain gage, and other associated components. Fiber optic cable is also used to connect the two PLC's which are approximately 2000 feet apart. Refer to the system block diagram for the basic configuration.

Powerhouse SCADA and Lock and Dam SCADA Connection

A fiber optics link is used to connect between the adjacent hydropower plant SCADA system and the Lock and Dam system. Headwater, tailwater, gate positions, spillway discharge (cfs) and precipitation is transmitted every 15 minutes from the Lock and Dam to the powerhouse. Turbine discharge, unit megawatts and total discharge are transmitted every 15 seconds from the powerhouse to the Lock and Dam. The powerhouse SCADA system is connected to the Little Rock District Hydraulics branch and to the upstream Ozark powerhouse. The Ozark powerhouse will eventually be connected to a future Ozark Lock and Dam SCADA system. The communication protocol utilizes Allen Bradley's Data Highway Plus which is supported by both SCADA systems. The automatic exchange of data eliminates the need for telephone communications between each site and helps to assure navigational pool levels are maintained. This connection also assures timely notification during a powerplant load rejection.

Gate Position Sensing

Tainter gates positions are determined by rotational potentiometers located at each gate. The potentiometers are connected to a shaft on the bull gear through a chain driven system and gears. The potentiometers are supplied with a 4-20 mA current loop from an analog input module. Details are included which show how the connections are made. The calibration of the potentiometers is determined by stop logging one gate and raising the gate in one foot intervals and recording the potentiometers output at each level. These values are put into a computer program which curve fits the data into an equation. Once the equation is determined, the PLC is programed with the equation to input the gate opening value to the SCADA system based on the current loop value. Refer to the gate calibration detail. Attempts were made to calibrate the gates through geometric

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analysis, but variations in the system, such as gear losses, cable stretch, and other factors resulted in inaccurate calculations. Our hydraulics engineering section desires to read gate positions to 1/100 of a foot (1/8 inch) accuracy. We have designed our system close to this, but cable stretch (approx 1 inch) due to temperature changes makes this accuracy impossible at all times.

SCADA System Functions

The spillway gate control system includes the following major system functions:

- Control of each individual gate (raise, lower, stop, and disable).
- Control of a group of gates (via automatic gate control).
- Limit Checking, Status Checking and Alarming
- Man-Machine Interaction
- Flow calculations
- Graphic Displays
- Log and Report Generation and printing
- Calendar and Clock Functions
- Data Acquisition
- Device Tagging
- Operator Notes
- Communication with Programmable Logic Controllers (PLC's)
- Communication with Dardanelle power plant SCADA system.
- Individual Gate enable/disable function. This enables or disables flow calculations and control functions for the selected gate.
- Automatic startup and failover of system
- System surveillance for improper or uninitiated control

actions.

- SCADA system control disable function - disables control action but leaves status inputs active.

- Refresh all scanned data, automatically and on operator command (poke point)

- Trending of real time and historical data

SCADA Control Modes

The operator is able to select "Manual" or "Automatic" control modes. In manual mode the Operator will manually control individual gates via screen poke points to the SCADA system. In the automatic mode the operator will enter a total spillway discharge setting (flow in cfs) and the SCADA system will perform calculations to determine the necessary position of each gate on the spillway to achieve the total spillway discharge setting. After the system has determined the necessary gate feet to achieve the discharge set point, the system will initiate gate movements (automatic gate control). The system will also accept total gate feet setting (total gate feet for the entire spillway) and the SCADA system will perform calculation and make changes to the spillway gates to achieve the total gate feet opening. The SCADA system will allow the operator to select either gate feet or flow when in the automatic mode. Discharge input will be the default mode of automatic gate control.

LESSONS LEARNED

These recommendations are based on the Little Rock Districts experience with hydropower, Lock and Dam, and military project SCADA systems. Many recommendations are specific to our projects and may not be applicable for all SCADA projects.

- Get Good TVSS equipment meeting current IEEE and UL standards. Specify multiple levels of protection (i.e., place protectors at the distribution panels, at power supply to the equipment, and on input output points).

- If absolute encoders are used, provide backup power to the encoder so that in case of primary power loss the encoder does not loss its position

- Carefully determine the need for full time printing of operator actions. In most cases operator logs are stored on the computer system and available for review. The primary time in which hard copies are required is when the system fails and knowledge of operator actions leading to the failure are critical to the recovery of the system. We have specified printing of operator actions on all of our systems. However, the day to day operation personnel do not always replace paper and have been known to disconnect the printer because of noise. It is recommended that all programming changes be printed. The printing of operator actions should be selectable through an MMI poke point.

- If dual printers are specified then do not require automatic switching of the printers. Switching to a backup printer if the primary printer fails is not a supported function by many SCADA software vendors.

- If the computer master station software is accessible through different computer monitors then be sure the SCADA vendor developed each different display with monitor display drivers specific to the monitor being used. Otherwise, the screens will not appear properly on the second monitor. This is especially important when remote access laptop are used.

- The color scheme used on alarm displays vary from vendor to vendor and may not be adjustable. Red is typical for an alarm state. However, non alarm states, etc. may vary. Allow the SCADA integrator varying options on color schemes, but require color schemes to be Government approved.

- Alarms that are acknowledged and no longer active should be deleted from an alarm page automatically.

- Do not allow operators to have access to the operating system. Only programmers should have this access. We have had several instances where operators have crashed the system.

- Documentation is essential. Insist that all custom software settings, and programs be fully documented. Reject any software documentation that is not complete. Be sure that reviewers are familiar with software programs.

- Keep all electronic components in controlled environments. Do not locate PLC's on Dam structures without being in a conditioned environment. If electronic equipment is located outdoors, provide a sun shield/roof over equipment.

- Warranty should require 48 hour response time.
- I/O point's list should include detailed description of signal type (i.e., analog, 120 Volt, 4-20 mA, software controlled, Contractor to determine,etc.)
- Include a minimum of eight hours of unstructured testing during factory and field testing. This allows reviewers an opportunity to test system functions that may come up during testing, but no specific tests were included in a structured test plan. Also, require the Contractor to furnish testing equipment for these unstructured tests.
- Interfaces between two different SCADA systems should mandate the interface software. Government furnished software will assure version compatible. If the systems happen to be directly compatible then the Government software does not have to be used.
- One line diagrams should indicate all external devices, but do not indicate the specific PLC devices that are required to interface to these devices. Different equipment vendors may utilize different means to interface.
- All training should be video taped. A video camera operator should be provided to assure good video quality. Complex computer interactions should be video taped closeup.
- Any database point or set point that requires frequent changes should be accessible via an MMI display poke point that leads the user to the appropriate screens.
- Include a requirement that does not allow scrolling or zooming to view parts of one display. The display should be completely visible without the operator having to scroll or zoom.
- Specify that any spare PLC modules that are be installed in the PLC rack be fully rack addressed and ready for use in ladder logic programming.
- Specify a list of all displays that you want the operator to have access too in the specifications. If possible develop layouts of essential screens and include in the specifications.
- Require that operation and maintenance documentation be

submitted in two stages with two separate review periods. Review documentation prior and during factory acceptance testing. All comments should be incorporated prior to beginning field acceptance testing. The second review period will be done during field testing and training. Ask trainees to comment on items that are not adequately addressed and provide these comments to the Contractor. This will help to assure that good documentation will be provided and allow the users to have input on what they need. Require that documentation be submitted at least two weeks prior to testing. Ask for longer if adequate personnel are not available for

- SCADA systems should not be contracted utilizing the design build contract method. If you put out an SCADA contract as a design build project then the specifications for a design build project should be very specific regarding the SCADA functions to be provided. If you don't specify the requirements, you will only get the minimal functional system. Do not count on a design build contractor to provide a good SCADA system without very specific specifications.

- Require that all complicated control's systems be fully simulated during FAT. Do not allow software emulators since they will not represent how the system will actually work.

- When using a SCADA system to control tainter gates with existing limit switches be sure to include requirements for the Contractor to bypass the limit switches. This often requires bypassing existing relays which provide safety features. Include requirements to maintain these safety features. These features include fast and slow rate of change alarms for the gate movement, and maximum time allow for gate movement. Do not bypass overtravel limit switches.

- It is important that operations personnel be at the factory acceptance testing. They provide valuable incite into the facilities operational requirements. In addition they may alert you to a possible problem with the system requirements and allow fixing the problem prior to full system implementation.

CONCLUSION

SCADA technology is constantly changing. With each new technology there are new problems and solutions. The Little Rock District continues to explore and develop SCADA requirement. We would like to offer our assistance to other Corps district who plan to start utilizing SCADA systems and more specifically to those who plan new Lock and Dam SCADA systems. SCADA systems are here to stay and the more we share information on each projects problems and solutions the more we will benefit in future projects.

REFERENCES

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